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# ELK MORTALITY IN THE CLEARWATER DRAINAGE OF NORTHCENTRAL IDAHO

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**Abstract:** Habitat condition and hunter density may affect mortality rates of elk (*Cervus elaphus*), and therefore, the amount of recreational opportunity offered hunters. Thus, we radio-monitored 121 elk in the forested habitats of northcentral Idaho during 1986–91 to determine cause-specific mortality. Sixty-nine deaths recorded during this period included: 43 recovered rifle kills, 8 rifle wounding losses, 4 archery wounding losses, 2 recovered archery kills, 3 poaching kills, and 9 other mortalities. Eighty-six percent of all elk deaths occurred during September and October and were associated with hunting. Annual survival rate of cow elk was 0.886 (SE = 0.094). Annual survival rate of bull elk was 0.600 (SE = 0.063). The probability of mortality during the hunting season was modelled with stepwise logistic regression from habitat and hunter density variables. The probability of mortality increased with road and hunter densities, and was lower in areas with highly broken or dissected terrain. Estimating cause-specific mortality is integral to population management and modelling. Mortality models, along with improved population estimation methods, and habitat monitoring techniques have the potential to predict the effects of habitat change on populations and how this may affect recreational opportunity. Mortality models also may help determine elk vulnerability during the hunting season.

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Determining survival and mortality rates is integral to population management and modelling (Caughley 1977). Radio telemetry allows monitoring individual animals for specific causes and timing of mortality (Heisey and Fuller 1985, Nelson and Mech 1986, White et al. 1987, Bartmann et al. 1992). This information can be used to adjust harvest strategies and develop population models to predict the effects of management decisions. Identifying the causes of mortality is especially important in hunted species. Wildlife managers usually can control the aspects of harvest (e.g., hunter numbers, season timing and length, type of legal animal), but often cannot control habitat conditions.

Timber harvest and the associated increase in access have significantly affected elk (Lyon et al. 1985). Several studies have documented the effect of roads on the habitat-use patterns and behavior of elk and to some extent hunter success and distribution (Basile and Lonner 1979, Irwin and Peek 1979, Edge et al. 1985, Lyon et al. 1985). These and other studies have resulted in guidelines and models that help predict the

impacts of timber harvest and road building on the summer habitat use patterns of elk (Black et al. 1976; Lyon 1979, 1983; Leege 1984). Although Leege (1976) and Thiessen (1976) associated increased access and logging with declines in elk numbers, a direct link between access and logging with elk harvest mortality has not been documented. Thus, we determined the mortality rates of adult cow, yearling bull, and  $\geq 2$ -year-old bull elk; determined the causes and timing of mortality; and modelled bull elk mortality from habitat condition and hunter density.

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## STUDY AREA

Our study area was north of the Clearwater and Lochsa rivers in northcentral Idaho. The area was approximately 1,600 km<sup>2</sup> in size and was located primarily within the Clearwater National Forest. Physiography was characterized by small, steep-sided drainages. Elevations ranged from 425 m at Syringa, Idaho, to 2,030 m on Castle Butte.

Annual precipitation at Fenn Ranger Station near the mouth of the Lochsa River averaged 90 cm, most (51%) of which fell from November through March. Temperatures recorded at Fenn Ranger Station ranged from a January average of -1.6 C to a July average of 21.3 C, with a mean annual temperature of 9.7 C.

Vegetation in the study area ranged from dry ponderosa pine (*Pinus ponderosa*)/Douglas-fir (*Pseudotsuga menziesii*) types at lower elevations to Engelmann spruce (*Picea engelmannii*)/subalpine fir (*Abies lasiocarpa*) types on the heights. Fire played a major role in shaping landscape patterns and about 25% of the area was seral shrubfields with grass/forb understories. Another 25% was mixed open timber/shrubfields and 50% consisted of closed canopy forest (>60% crown closure).

Land uses included commercial timber harvest, limited livestock grazing, fishing, camping, and hunting. There was a 28-day either-sex archery season during September and a 26-day rifle season for any antlered elk during October. Elk density on the study area during summer was roughly 1 elk/km<sup>2</sup> and post season bull:cow ratios ranged from 14:100 on the western portion of the study area to 35:100 on the eastern portion (Id. Dep. Fish and Game, Statewide Surveys and Inventory, Project W-170-R-15, Boise, unpubl. rep.).

## METHODS

We captured 121 elk from a helicopter by remotely injected darts filled with 3–4 mg Carfentanyl citrate. Elk were eartagged, radiocollared, and classified as either cow, yearling bull, or ≥2-year-old bull elk. Some elk were collared on winter ranges but most were collared during May and June. Collars and ear tags were labeled with a request to return the collar to the Idaho Department of Fish and Game. Collars were equipped with mortality switches that changed pulse rates after being motionless for 4 hours. We estimated age from tooth replacement and wear (Quimby and Gaab 1957).

We relocated radio-collared elk from the air at 1- to 4-week intervals during the non-hunting season and 2–3 times/week during the hunting season. We recorded the latitude and longitude (from the aircraft's LORAN-C navigation system) of each radio-collared elk and determined if the animal was alive. If a mortality signal was detected, the animal was relocated from the ground, and cause of mortality was determined by field necropsy. The public was notified prior to hunting season about the presence of radio-collared elk and encouraged to return collars and information about the kill location and the date of kill. Hunters received a \$10.00 reward and information about the elk they killed when collars were returned. We do not believe that the presence of radio collars influenced elk mortality because very few hunters reported seeing the radio collar before killing the elk.

We evaluated LORAN-C system error by comparing coordinates from the aircraft LORAN-C with map coordinates (1:24,000) of 10 prominent landscape features. We evaluated radio-tracking error by hiding radio collars and having observers locate these collars aerially. Latitude and longitude coordinates were converted to Universal Transverse Mercator (UTM) coordinates, and total error was the distance between the mapped location of fixed points or hidden collars and the LORAN-C location. We used estimates of system error to calibrate the LORAN-C receiver. Mean error (system error plus radio tracking error) during the study was  $473 \pm 131.4$  (SE) m. These coordinates were used to estimate autumn use areas and seasonal home ranges. They were not used for point estimates of habitat characteristics. We were interested in the use of habitats on the home range level (Johnson 1980) and we considered this level of error acceptable.

## Annual Survival

We calculated annual survival rates, 1 July–30 June, with the staggered entry Kaplan-Meier procedure (Kaplan and Meier 1958, Pollock et al. 1989), and used the log-rank test (Pollock et al. 1989) to make pairwise comparisons between the survival functions of cow, yearling bull, and ≥2-year-old bull elk. We treated the uncensored data as a binomial process and used logistic regression to test for difference in survival among years (Bartmann et al. 1992) and a Chi-square analysis to test for differences among the annual survival rates of cow, yearling bull, and ≥2-year-old bull elk.

Table 1. Annual survival rate estimates ( $\hat{S}$ ) of radio-collared elk, Clearwater drainage, northcentral Idaho, 1986–91.

Sex	Year	No. radio-collared elk	$\hat{S}$	SE( $\hat{S}$ )
Bull	1 Jul 1986–30 Jun 1987	30	0.733 <sup>a</sup>	0.060
	1 Jul 1987–30 Jun 1988	40	0.589	0.058
	1 Jul 1988–30 Jun 1989	42	0.560	0.070
	1 Jul 1989–30 Jun 1990	28	0.585	0.070
	1 Jul 1990–30 Jun 1991	29	0.552	0.092
Cow	1 Jul 1986–30 Jun 1987	9	1.000 <sup>a</sup>	
	1 Jul 1987–30 Jun 1988	9	0.875	0.093
	1 Jul 1988–30 Jun 1989	11	0.808	0.118
	1 Jul 1989–30 Jun 1990	9	0.778	0.130
	1 Jul 1990–30 Jun 1991	8	1.000	

<sup>a</sup> Survival rates did not vary among years for bull ( $G = 2.85$ , 4 df,  $P = 0.584$ ) or cow elk ( $G = 5.38$ , 4 df,  $P < 0.250$ ); logistic regression.

Mortality Model

We used a weighted bivariate normal ellipse (Samuel and Garton 1985, Ackerman et al. 1990) to describe the areas used annually by bull elk during August, September, and October, a period including the hunting season. This method was selected because it is robust to small sample sizes (Samuel and Garton 1985), adequately identifies the general location of the area used during autumn (Boulanger and White 1990), and we were interested only in the relative proportion of independent variables within each area and not its size. Latitude and longitude coordinates from radio relocations were converted to UTM coordinates and a 90% weighted bivariate normal ellipse was estimated for each bull elk ( $n = 143$  elk-years) using HOMERANGE (Ackerman et al. 1990).

A geographic information system (GIS) (GRASS, Westervelt 1988) was used to measure habitat characteristics within each 90% ellipse. The GIS consisted of data bases from LANDSAT imagery (vegetation classification), a digitized road and hunter density map (1:24,000 topographic maps), United States Geographic Service Defense Mapping Agency topographic data, and an elk use layer consisting of the individual ellipses (there was extensive overlap among ellipses, but each ellipse was treated as a separate polygon). We estimated the percent of each ellipse in 3 habitat categories: timber (timber with >60% canopy closure), open timber (timber with >20% but ≤60% canopy closure), and shrubfield or clearcut (timber canopy closure <20%). Open and closed road density (km road/km<sup>2</sup>), hunter density (hunter days/km<sup>2</sup>), mean slope, and circular standard deviation of aspect (Zar 1984:431) also were estimated. The slope and aspect variables were used as indices to topographic roughness. Mean slope indexed the

overall steepness of the area and circular standard deviation of aspect indexed brokenness or complexity of the area. GRASS is a raster based system, and slope and aspect are measured as the area within categories of each variable. Aspect was divided into 73 categories, 72 of 5° each and 1 no-aspect category (flat), slope had 91 categories, 90 of 1° each and 1 category for 0° (flat) slope. The flat category was not included in the calculation of the circular standard deviation of aspect, but was included in the mean slope calculation. Hunter density was determined from telephone surveys and random sampling at egress roads (L. J. Nelson, Annu. Big Game Harvest Estimates, Id. Dep. Fish and Game, unpubl. rep.; M. Yuan and D. Smith, Inst. for Tourism and Recreation Res., Univ. of Mont., unpubl. data). Hunter density was estimated for 4 subunits within the study area and a weighted average was calculated for each 90% ellipse that included >1 subunit.

We used stepwise logistic regression (Hosmer and Lemeshow 1989, Wilkinson 1990, Steinberg and Colla 1991) to model the probability of bull elk (both age classes combined) mortality from August to October (included the archery and rifle hunting seasons). The dichotomous classification of bulls surviving or harvested during the hunting season was treated as the dependent variable. The independent variables were percent timber, percent open timber, percent shrubfield, percent flat ground, open road density, closed road density, hunter density, mean slope and circular standard deviation of aspect within the area used by bull elk during August–October. Variables entered or were removed from the model at the 0.15 significance level (Steinberg and Colla 1991).

We evaluated models with the log likelihood ratio statistic that tested the hypothesis that all

Table 2. Cause of mortality for radio-collared bull elk, Clearwater drainage, northcentral Idaho, 1986–91.

Year	No. radio-collared elk	Censored	Cause of mortality									
			Recovered rifle kill		Rifle-wounding loss		Recovered archery kill		Archery-wounding loss		Poaching	
			No.	%	No.	%	No.	%	No.	%	No.	%
1 Jul 1986–30 Jun 1987	30		5	17	1	3			2	7		
1 Jul 1987–30 Jun 1988	40	2	9	23	3	8			1	3	2	5
1 Jul 1988–30 Jun 1989	42	7	7	19	2	6	1	3	1	3	1	3
1 Jul 1989–30 Jun 1990	28	2	9	34	1	4						
1 Jul 1990–30 Jun 1991	29	2	11	35	1	3	1	3				
											1	4
											4	11
											1	3
											1	3

coefficients except the constant were zero. Nested models were evaluated relative to each other with the G-statistic, and model fit was evaluated with Hosmer-Lemeshow statistics and model prediction success tables. Individual model coefficients were evaluated with the *t*-ratio (Hosmer and Lemeshow 1989, Steinberg and Colla 1991).

RESULTS  
Survival and Cause-specific Mortality

Survival functions and annual survival rates were similar for yearling and ≥2-year-old bull elk ( $\chi^2 = 0.19$ , 1 df,  $P > 0.50$  and  $\chi^2 = 0.86$ , 1 df,  $P = 0.353$ , respectively), and those age classes were combined. The 5-year weighted average survival of bull elk was 0.600 (SE = 0.063). Survival functions differed between bull and cow elk ( $\chi^2 = 14.82$ , 1 df,  $P < 0.001$ ), as did annual survival rates ( $\chi^2 = 11.04$ , 1 df,  $P < 0.001$ ). The 5-year weighted average survival of cow elk was 0.886 (SE = 0.094). Survival rates did not vary among years for bull ( $G = 2.85$ , 4 df,  $P = 0.584$ ) or cow elk ( $G = 5.38$ , 4 df,  $P < 0.250$ ) (Table 1).

Sixty-four bull elk died during the monitoring period (Table 2): 41 recovered rifle kills, 8 rifle wounding losses, 2 recovered archery kills, 4 archery wounding losses, 3 poaching kills, and 6 other mortalities. Five cow elk died; 2 recovered rifle kills and 3 other mortalities. Eighty-six percent of all elk mortalities occurred during September–October and were associated with hunting.

Variables Influencing Mortality

We measured the habitat characteristics of 143 areas used by 101 bull elk (42 bulls survived >1 year) during autumn (Table 3). Habitat characteristics were not the same in areas used by surviving and harvested bull elk ( $\chi^2 = 23.17$ , 8 df,  $P = 0.003$ ). Areas used by surviving bull elk had lower open road and hunter densities and they were steeper, more broken, or more dissected. Vegetation and closed road densities were similar in the areas used by surviving and harvested elk (Table 3).

Hunting Season Mortality Model

The simplest multivariate model that adequately predicted bull elk mortality (*m*) during hunting season (Hosmer-Lemeshow statistic = 5.111, 6 df,  $P = 0.530$ ) used road density, bro-

Table 3. Independent variables and their Chi-square score from the first step of the logistic regression for surviving (*n* = 93) and harvested (*n* = 50) bull elk from autumn use areas, Clearwater drainage, northcentral Idaho, 1986–91.

Variable	Surviving		Killed		X <sup>2</sup>	P
	$\bar{x}$	SE	$\bar{x}$	SE		
Aspect (S')	194.392	1.229	189.897	1.755	4.445	0.035
Slope ( $\bar{x}$ )	14.251	0.363	13.086	0.603	3.061	0.080
Timber (%)	42.194	1.375	45.160	2.064	1.521	0.217
Open timber (%)	23.065	1.051	20.820	1.521	1.532	0.216
Shrubfield (%)	33.194	1.429	30.800	2.130	0.926	0.336
Open road (km/km <sup>2</sup> )	0.234	0.032	0.442	0.071	8.897	0.003
Closed road (km/km <sup>2</sup> )	0.013	0.005	0.025	0.016	0.823	0.364
Hunters (hunter days/km <sup>2</sup> )	5.852	0.199	6.906	0.319	8.277	0.004

kenness and complexity of terrain, and hunter density (Table 4):

$$m = \frac{e^u}{1 + e^u}$$

where *u* = 4.784 + 1.050 open road density (km/km<sup>2</sup>) – 0.035 aspect (S') + 0.169 hunter density (hunter days/km<sup>2</sup>). The probability of mortality increased with increasing road and hunter densities and was lower in areas of more broken or dissected terrain. Overall prediction success of this model was 59.8%.

DISCUSSION

Cow Elk Mortality

During the study there was no general rifle season for cow elk. However, Native Americans could harvest both sexes year-round and archery seasons were open for either-sex. A limited number of controlled hunt permits were available on a portion of the study area, but no permit holders harvested radio-collared cow elk. Two cow elk were killed by Native Americans during the study, one during the general rifle season and one on winter range in February. Three cow elk died during winter from unknown causes.

We estimated annual female survival at 88.6%. Although cow elk were hunted, few animals were harvested and overall hunter effort was low for cows. In New Mexico, White (1985) estimated the survival rate of unhunted elk at 91%. In northern Idaho where cow elk are hunted in the general rifle season, Leptich and Zager (1991) estimated a 12% mortality rate for cows. All of the mortality was associated with hunting or poaching and 55% was attributed to rifle hunting, 27% to rifle wounding loss, and 18% to poaching. In Colorado, Freddy (1987) reported

that 22% of 58 radio-collared cow elk died during a 4-year period. Harvest (9%), illegal harvest (5%), wounding loss (3%), and winter mortality (5%) were the causes of death.

Bull Elk Mortality

Over 90% of bull elk mortality was caused by hunters during the general rifle season. Hunting has been documented as the major source of bull mortality in several elk populations (e.g., Peek et al. 1967; Kimball and Wolf 1974, 1979; White 1985; Leptich and Zager 1991). We found similar mortality rates for both age classes of bull elk even though a majority of hunters said they preferred harvesting branch-antlered bulls (McLaughlin et al. 1989). The annual bull mortality rate (40%) we observed was similar to those calculated by Kimball and Wolfe (1974) during 1951–72 (42%), but was lower than the estimates they observed in later years (78%) (Kimball and Wolfe 1979). Kimball and Wolfe

Table 4. Logistic regression results from radio-collared bull elk (*n* = 143 elk-years), Clearwater drainage, northcentral Idaho, 1986–91.

Variable	P-value	Parameter estimate	t-ratio
Constant	0.167	4.784	1.381
Open road (km/km <sup>2</sup> )	0.053	1.050	1.993
Aspect (S')	0.048	–0.035	–1.974
Hunters (hunter days/km <sup>2</sup> )	0.066	0.169	1.839
Closed road (km/km <sup>2</sup> )	0.308		
Slope ( $\bar{x}$ )	0.289		
Timber (%)	0.860		
Open timber (%)	0.368		
Shrubfield (%)	0.323		

(1974, 1979) used tagging methods to estimate mortality and bull elk were hunted under general bull seasons after 1968 and with a permit system before 1968. In New Mexico, White (1985) estimated the survival rate of the hunted segment of an elk population at 55% (45% mortality) when only branch-antlered bulls could be legally harvested. Leptich and Zager (1991) estimated a 55% mortality rate for bull elk in northern Idaho using methods similar to ours.

### Bull Elk Mortality Model

Although research has indicated that elk habitat use patterns change in response to logging and increased road density, it has been difficult to link habitat condition to survival or productivity in big game animals (Peek *et al.* 1982). Mortality models based on habitat condition begin to establish that link. Increasing road and hunter densities increased the probability of mortality and highly broken or dissected terrain reduced the probability of mortality. Other studies have implicated increased hunter densities and easier access to increased vulnerability in elk. Legee (1976) associated increases in hunter numbers, access, and decreasing cover with a decline in winter elk numbers on part of our study area. Hershey and Legee (1982) did not see the same associations in a nearby study area, but did determine that elk using areas near roads were more likely to be harvested than those further away. In southwestern Idaho, Thiessen (1976) associated declines in elk numbers with overharvest of cow elk made possible by a combination of increased access and high levels of hunting opportunity. More recent work has linked mortality and habitat condition (Leptich and Zager 1991, Unsworth and Kuck 1991) and has helped explain how hunter and elk density may interact to affect harvest (Vales *et al.* 1991).

Habitat use studies have established that elk prefer dense cover during late summer and autumn. The suggested reasons for this disproportionate use have been the availability of succulent forage (Skovlin 1982) and the need for security during the autumn hunting and breeding seasons (Hershey and Legee 1982, Irwin and Peek 1983). Considerable effort has been applied to quantifying the characteristics of security areas (Black *et al.* 1976, Irwin and Peek 1983, Lyon *et al.* 1985, Hills *et al.* 1991) and recently security has been defined as: an area because of its geography, topography, vegetation, or a combination, that will hold elk during

periods of stress (Lyon and Christensen 1992). Our modelling effort indicated that topographic variables were the most important measures of security in the Clearwater area and a separate analysis of this data set indicated that bull elk may decrease their chances of survival by selecting patches of timber in roaded habitats (Unsworth and Kuck 1991). Edge and Marcum (1991) also associated topographic variables with elk security and they recommended that topographic variables be considered when locating roads and other sources of disturbance in elk habitat.

### MANAGEMENT IMPLICATIONS

Summer habitat effectiveness models (e.g., Black *et al.* 1976, Lyon 1983, Legee 1984) predict how elk modify their habitat use patterns during summer to adjust to disturbance, but provide no link to mortality and are not appropriate during hunting seasons. Mortality models may provide a reasonable way to evaluate the link between habitat condition and mortality. As geographic information systems become more available, existing data sets could be reexamined with our methods and other mortality models could be developed. As with most models, application of our model to other areas should be done with caution. All of the autumn use areas on our study area had road densities less than 2.5 km/km<sup>2</sup> and 80% of our observations were in road densities below 0.625 km/km<sup>2</sup>. We believe our model is a reasonable predictor of mortality at road densities below 1.5 km/km<sup>2</sup>, but above this level 95% confidence intervals are large. In northern Idaho, additional research is underway that may improve mortality estimates at higher road densities (Leptich and Zager 1991).

Several variables we did not directly evaluate may be important, and future models should evaluate elk density, hunting season length, weather, and possibly hunter strategy variables. On our study area, the areas used by surviving and harvested elk overlapped extensively, and we do not believe the differences we observed in mortality rates were due to differences in elk density. The relationship between hunting season length and hunter density needs to be evaluated in future models. It is likely that elk are more vulnerable where high hunter densities are compressed into shorter seasons.

Other research suggests closing roads may reduce mortality rates for elk (Leptich and Zager

1991). In areas with high hunter densities and general bull seasons, it is unlikely that road closures alone will reduce bull mortality to acceptable levels. We are not aware of an elk population that is hunted (except those that are hunted under a very limited number of controlled permits) where it has been shown that environmental or habitat factors are limiting the male cohorts of the populations. Habitat is definitely important to the long term viability of elk populations, but we believe that elk populations are more likely to be controlled by harvest than by limits in cover or forage. In most years, hunters, their efficiency modified by road density and topography, control elk populations.

Interagency wildlife population and habitat management is imperative for proper management of elk populations, and managers also must begin to consider what factors contribute to a quality hunting experience. Hunters and other wildlife enthusiasts are no longer satisfied with the populations that result from the maximum harvest of bull elk; nevertheless, most hunters are reluctant to accept the loss of recreational opportunity resulting from season restrictions imposed by wildlife agencies in response to easier access to elk habitat. Mortality models, along with improved population estimation methods and habitat monitoring techniques have the potential of predicting the effects of habitat change on populations and how these may change recreational opportunity.

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